



*Original Research*

## **The Acute Effects of Static Stretching Compared to Dynamic Stretching with and without an Active Warm up on Anaerobic Performance**

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### **ABSTRACT**

*International Journal of Exercise Science 10(1): 53-61, 2017.* The Wingate Anaerobic Test (WAnT) has been used in many studies to determine anaerobic performance. However, there has been poor reporting of warm-up protocols and limited consistency between warm-up methods that have been used. With the WAnT being such a commonly-used test, consistency in warm-up methods is essential in order to compare results across studies. Therefore, this study was designed to compare how static stretching, dynamic stretching, and an active warm-up affect WAnT performance. Ten recreationally active participants (5 males, 5 females) with a mean (SD) age of 23.3 (0.7) volunteered for this study. Subjects were randomized to a specific order of five warm-up protocols, which were performed on individual days followed by a WAnT. Peak power, mean power, power drop, and fatigue index were compared for each trial using a repeated measures ANOVA. For peak power, results revealed that warm-up protocol had a significant effect,  $F(4,36) = 3.90$ ,  $p = .01$ , partial  $\eta^2 = .302$ . It was hypothesized that the dynamic stretching would lead to greater peak power than the static stretching protocol. However, results of post hoc analyses failed to detect a significant difference ( $p = .065$ ). For the other measured variables no significant differences were found. The findings from this study suggest that warm-up protocols may have significantly different impacts on peak power during the WAnT. Additional research should use larger sample sizes and further explore these warm-up protocols. Developing a standardized warm-up protocol for the WAnT may improve consistency between studies.

**KEY WORDS:** Warm-up, stretching, wingate, anaerobic power

### **INTRODUCTION**

Many warm-up protocols are developed by trial and error and are not always scientifically tested (4). Nevertheless, establishing a warm-up that maximizes performance is important. A warm-up may benefit performance if it increases body core temperature, nerve impulse

transmission, and metabolic activity, while it decreases joint and muscle stiffness (20). However, there are inconclusive findings on the effectiveness of various warm-up protocols on anaerobic performance (3). In previous studies, dynamic stretching has been found to increase muscular and sprint performance (21,31) while static stretching was found to reduce performance and lower contractile force of the muscles (13). However, more recently, there have been a number of studies reporting that static stretching prior to performance has no detrimental effects (2,21,27,31). This lack of consistency may also be associated with methodological differences including training status of participants, gender, warm-up duration and intensity, and how anaerobic performance was assessed (i.e., sprinting, vertical jump) (2,27,31,32). One standardized test of anaerobic power is the Wingate Anaerobic test (WAnT). Presently, there is limited research investigating how various warm-up protocols affect WAnT performance (14,16).

Although the WAnT has been used in many studies to determine anaerobic performance (peak and average power output) (3,15,19), to date there has been poor reporting of the warm-up protocols used prior to performance (8,17,28) and limited consistency among the warm-up methods that have been reported (18,26). Even with the inconsistency in warm-up methods prior to WAnT performance, only two studies have observed the effects of stretching on WAnT performance (14,16). Franco and colleagues (2012) concluded there was a consistent increase in total power after all stretching exercises (i.e., dynamic, static, and proprioceptive neuromuscular facilitation) when compared to no stretching. The researchers noted, however, that since there are few WAnT stretching studies in the literature, they had to compare their results to stretching studies performed with other anaerobic power tests (e.g., vertical jump) (14). Additionally, all stretching protocols were performed with an active warm-up, which may have affected performance and masked the effects of various stretching techniques. Therefore, there is need for additional research to observe the effects of warm-up techniques (with and without stretching) on WAnT performance in order to improve comparability among studies using the WAnT.

Since previous research examining stretching on WAnT performance required subjects to perform an active warm-up before all conditions, it is possible that any negative effects or positive benefits from the stretching protocols were either influenced or masked by the active warm-up. In order to further investigate, this study included five conditions to specifically examine how dynamic stretching and static stretching with and without an active warm-up affect WAnT performance in order to build on previous research (14). It is important to examine how stretching with and without an active warm-up affect WAnT performance in order to begin to develop a standardized warm-up for the WAnT. Moreover, with the WAnT being such a commonly-used test of anaerobic performance, consistency in warm-up methods is essential if individuals wish to compare results across studies. Developing a standardized warm-up for the WAnT will also help control variability within and between studies.

Therefore, this study was designed to investigate a dynamic stretching routine and a static stretching routine, with and without an active warm-up affect on WAnT performance. The

purpose of this study was twofold: (1) to compare dynamic and static stretching each to a general warm-up in order to investigate how they affect WAnT performance and (2) to examine if the combination of either type of stretching with a general warm-up produced greater WAnT performance. It is hypothesized that dynamic stretching would lead to greater performance on the WAnT compared to static stretching. Additionally, it was also hypothesized that the inclusion of a general warm-up with stretching would lead to greater performance when compared to either stretching or a general warm-up alone.

## METHODS

### *Participants*

This study was designed to compare two stretching protocols with a general warm-up on WAnT performance. Additionally, this study investigated if the combination of stretching with a general warm-up had either a positive or a negative impact on performance when compared to stretching alone. The variables measured in this study were peak power, mean power, power drop, and fatigue index. Using a large effect size of  $f = 0.5$ , a power of 80%, and assuming a strong correlation between repeated measures, a power analysis yielded a sample size of 10 participants.

Ten recreationally active participants (5 males, 5 females) volunteered for this study. Additional participant characteristics are detailed in Table 1. The experimental protocol was approved by the Human Subjects Institutional Review Board at the University. All subjects signed an informed consent document and completed a health and injury questionnaire. The subjects included in this study were considered low risk according to risk classifications of the American College of Sports Medicine (22). Additionally, all subjects were between the ages of 18-45, exercised 3-5 days per week for at least 30 minutes, were free of any known disease or injury that would inhibit WAnT performance, and were not currently involved in a regular stretching program. The participants were not informed of performance after any trial until the study was completed.

**Table 1.** Descriptive Characteristics of Participants.

	Males (N=5) Mean $\pm$ sd	Females (N=5) Mean $\pm$ sd
Age (yr)	22.0 $\pm$ 1.8	19 $\pm$ 2.4
Height (cm)	167.0 $\pm$ 8.2	158.0 $\pm$ 7.5
Weight (kg)	75.0 $\pm$ 9.9	49.0 $\pm$ 8.9
BMI	24.21 $\pm$ 2.2	19.6 $\pm$ 1.7

BMI = body mass index

### *Protocol*

For the standardized cycling warm-up, the subjects cycled at a low-moderate intensity (between 70-75 RPM) for five minutes with no resistance. At the end of each minute, a sprint was performed at maximal force for five seconds against 25% of their resistant load. After the

fifth sprint was completed, the participants cycled at low intensity for an additional minute against no resistance before performing the WAnT.

The dynamic stretching warm-up consisted of (1) military march, (2) walking lunge drill, (3) side step hurdle drill, (4) superman drill, (5) A-skips drill, (6) C-skips drill, (7) high knee walk drill, (8) lateral high knee drill, (9) skips for height drill, (10) toe touch drill, and (11) bounding drill. Each exercise was done for 20 meters, with the exception of the bounding drill, which was performed for 50 meters. This dynamic warm-up was developed by Leon et al. and is described as a purposeful dynamic stretching routine (20).

The static stretching warm-up consisted of (1) standing calf stretch, (2) kneeling Achilles tendon stretch, (3) seated hamstring stretch, (4) seated gluteus maximus stretch leaning forward with one foot over the leg, (5) standing quadriceps stretch, (6) lying lower back stretch, (7) seated groin stretch, and (8) kneeling hip flexor stretch. All stretches were held for 30 seconds each, with stretches 1–6 repeated twice for each limb. Stretches 7–8 only were performed once on each limb. This stretching protocol has been used in previous research investigating the effects of static stretching when combined with an active warm-up (29).

Following each of the five warm-up conditions, the participants performed a WAnT: subjects pedaling at their highest revolutions per minute (RPM) against 7.5% of their body mass in kilograms in resistance force for 30 seconds. During the last five seconds prior to the WAnT, the participants cycled at their maximal speed and the resistance force was manually dropped by the lab technician. This protocol is similar to other studies on recreationally active individuals (1,14,23). This study used the Monark Anaerobic Test software (V.3.3.0.0) from Vansbro, Sweden and tests were performed on a Monark Ergonomic 984E cycle. Variables that were measured consisted of peak anaerobic power, mean anaerobic power, power drop, and fatigue index. Testing took place at the same time each day and all testing sessions were separated by at least 48 hours to provide participants with sufficient time to recover. Also, participants refrained from caffeine intake at least four hours prior to testing, were asked to maintain their regular diet throughout the study, and were told to maintain regular exercise activity, but to avoid maximal exercise for at least one day prior to testing. Participants were asked to complete all testing sessions within five weeks of their first visit.

#### *Statistical Analysis*

Data on peak power, mean anaerobic power, power drop, and fatigue index were analyzed using a repeated measures ANOVA to determine differences ( $p \leq 0.05$ ) among conditions. Post-hoc analysis would be performed using t-tests with Bonferroni adjustments ( $p \leq 0.05$ ). The level of significance was established *a priori* as  $p \leq 0.05$ . The SPSS statistical package V. 19.0.0 (SPSS Inc., Chicago, IL) was used for data analysis.

## RESULTS

Repeated-measures ANOVA were conducted to determine the effect of warm-up protocol on WAnT performance, specifically peak power, mean power, power drop, and fatigue index.

For peak power, the results revealed that warm-up protocol had a significant main effect on WAnT performance,  $F(4,36) = 3.90$ ,  $p = .01$ , partial  $\eta^2 = 0.302$ . It was further hypothesized that the dynamic stretching protocol would lead to a greater peak power than the static stretching protocol. However, the peak power for the dynamic stretching protocol ( $M = 9.3$ ,  $SD = 1.8$ ) was not significantly different from peak power on the static stretching protocol ( $M = 8.5$ ,  $SD = 1.3$ ),  $p = 0.06$ . Yet, Cohen's effect size (1992) value between dynamic stretching and static stretching suggested that dynamic stretching may have a small to moderate effect on WAnT performance ( $d = 0.48$ ) (7). All values for each condition can be found in Table 3.

**Table 3.** Mean peak power by condition.

Condition	Peak Power ( $W \cdot kg^{-1}$ ) M(SD)
Cycling	8.7 (1.4)
Dynamic Stretching	9.3 (1.8)
Static Stretching	8.5 (1.3)
Dynamic Stretching and Cycling	8.9 (1.4)
Static Stretching and Cycling	8.6 (1.2)

For the remaining outcome measures, no significant main effects were found between the warm-up protocols; mean power,  $F(4,36) = 2.22$ ,  $p = 0.08$ , partial  $\eta^2 = 0.198$ , power drop,  $F(4,36) = 2.29$ ,  $p = 0.07$ , partial  $\eta^2 = 0.203$ , and fatigue index,  $F(4,36) = 0.794$ ,  $p = 0.53$ , partial  $\eta^2 = 0.08$ .

## DISCUSSION

The purpose of this study was to investigate the effects of various stretching protocols on WAnT performance. The study compared a standardized cycling warm-up to a static stretching warm-up and a dynamic stretching warm-up. Additionally, this study examined the combination of an active warm-up with static stretching and the combination of an active warm-up with dynamic stretching in order to determine if an active warm-up in addition to stretching affected performance. Previous research investigating the effects of warm-up protocols on the WAnT used an active warm-up with all protocols, possibly limiting their ability to detect differences among various types of stretching affect on performance (14). Prior to the commencement of this study, it was hypothesized that the dynamic stretching warm-up would be most beneficial on WAnT performance. Past studies have concluded that a proper warm-up, one that increases flexibility and range of motion while elevating body temperature and blood flow, will improve performance, specifically maximal anaerobic power (5,10,25). Therefore it was hypothesized that this study would yield similar results.



Upon completing the study, an overall difference was found between the warm-up protocols for peak power. However, when the post hoc analyses were conducted, there was no significant difference between the static and dynamic protocol as hypothesized ( $p = 0.065$ ). However, the Bonferroni adjustment is quite stringent and may have failed to detect a significance due to the small sample size in this study. When comparing dynamic stretching to static stretching, Cohen's effect size suggested that dynamic stretching may have a small to moderate effect on performance. The comparison between static and dynamic stretching approached significance and had a small to moderate effect, supporting studies that have concluded dynamic stretching to be more beneficial than static stretching prior to anaerobic performance output (6,10,31,32). However, since the differences found in this study were not significant this cannot be concluded with certainty. It should be noted that for 9 of the 10 participants, the static stretching warm-up led to the lowest peak power and average power on the WAnT. It appears that future research should focus more on dynamic stretching with and without an active warm-up on WAnT performance in larger sample sizes.

An area of concern when developing effective warm-up protocols is that an excessively long active warm-up could reduce performance due to muscle fatigue. An overly intense warm-up could potentially have a negative effect on performance (30). In order to avoid this, all individual warm-up protocols were under 15 minutes, similar to suggestions made by Bishop who recommended a limited active warm-up due to increased risk of fatigue (4). Based on the findings in this study, it does not appear that an active warm-up either positively or negatively affects WAnT performance. Dotan and Bar-Or (10) stated that a specific fatigue rate (around 46.6%) is associated with maximized performance on the WAnT (11). In this study, each condition had a mean fatigue index near fifty percent with no significant differences among any of the conditions. This led us to conclude that subjects maximized performance and that their performance was not significantly hindered by any of the five warm-up protocols performed prior to testing.

This study does have limitations that should be addressed. First, this study had a small sample size, which limited the ability to detect a difference among warm-up protocols. Secondly, although the participants were all recreationally trained and exercising 3-5 days per week for at least 30 minutes, some participants may have been more anaerobically trained than others. This may have affected the overall outcomes regarding how each warm-up protocol affected WAnT performance. Future studies should account for training status and type of training in order to determine if that alters which warm-up protocol may affect WAnT performance.

Despite these limitations, this study is one of the first to examine the effects of various warm-up protocols on WAnT performance. This study was designed to specifically observe effects of stretching routines with and without an active warm-up on WAnT performance. Franco et al. (14) compared static stretching, dynamic stretching, proprioceptive neuromuscular facilitation, and no stretching. They concluded that there was a consistent increase in total power after all stretching exercises compared to the no stretching condition. However, Franco et al. (14) stated that their findings could not be concluded with certainty because all their subjects performed

an active warm-up prior to the stretching routine. Yet, in this study, stretching protocols, with and without an active warm-up, were compared and still no significant differences were found among the various stretching methods. It is important to note that although there was no apparent improvement in performance following a warm-up, a warm-up did not have a negative or diminishing effect on performance. This finding is consistent with other studies (14,32) that observed the effects of various warm-ups on power output and related activities. Since a negative or positive effect on performance was not observed, it is suggested that a warm-up is still important prior to performance due to the injury reducing potential that was noted in previous studies (5,10,12,24).

In conclusion, an overall significant difference was found among the five warm-up protocols on peak power suggesting that warm-up protocols may affect WAnT performance. This is only one of few studies that investigates specific warm-up methods for WAnT performance, suggesting that additional research is needed to investigate various warm-up methods on WAnT performance. Given that the WAnT is a commonly used laboratory test to measure peak power, mean anaerobic power, and fatigue, it would be beneficial to standardize the warm-up in order to promote optimal performance and develop consistency among studies. Therefore, further research with larger sample sizes is needed to investigate various warm-up protocols in order to maximize WAnT performance. Additionally, further research should examine (1) how dynamic stretching affects WAnT performance and (2) if including an active warm-up with stretching protocols either improves or hinders WAnT performance compared to stretching alone. While this study used recreationally active individuals, future research should focus on warm-up protocols and their effects on WAnT performance in trained athletes since this test may be more commonly used in athletic populations.

Although the WAnT is performed on a cycle ergometer, the results on this test relate well to sports that rely on maximal anaerobic power and anaerobic capacity including sprinting and hockey (14). Along with evidence from previous research, athletes and coaches should use this data to choose the most appropriate warm-up to meet their specific needs. In this study, a negative effect on performance was not found for any of the five warm-up protocols examined. It was concluded that a warm-up protocol, as presented in this study, is not detrimental to anaerobic performance and simply acts as a method of preparation for performance while possibly reducing injuries.

## REFERENCES

1. Arslan C. Relationship between the 30-second wingate test and characteristics of isometric and explosive leg strength in young subjects. *J Strength Cond Res* 19(31): 658-666, 2005.
2. Behm DG, Chaouchi A. A review of the acute effects of static and dynamic stretching on performance. *Eur J Appl Physiol* 111(11): 2633-2651, 2011.
3. Bell W, Cobner D. The dynamics of distance, velocity and acceleration of power output in the 30-s Wingate Anaerobic Test. *Int J Sports Med* 32(21): 137-141, 2011.

4. Bishop D. Warm-up II: Performance changes following active warm up on exercise performance. *Sports Med* 33(483-498, 2003.
5. Cè E, Margonato V, Casasco M, Veicsteinas A. Effects of stretching on maximal anaerobic power: the roles of active and passive warm-ups. *J Strength Cond Res* 22(31): 794-800, 2008.
6. Christensen BK, Nordstrom BJ. The effects of proprioceptive neuromuscular facilitation and dynamic stretching techniques on vertical jump performance. *J Strength Cond Res* 22(61): 1826-1831, 2008.
7. Cohen, J. A power primer. *Psychological bulletin* 112(1): 155, 1992.
8. Collomp K, Le Panse B, Portier H, Lecoq A, Jaffre C, Beaupied H, Richard O, Benhamou L, Courteix D, De Ceaurriz J. Effects of acute salbutamol intake during a Wingate test. *Int J Sports Med* 26(71): 513-517, 2005.
9. Crombie IK, Irvine L, Williams B, McGinnis AR, Slane PW, Alder EM, McMurdo ME. Why older people do not participate in leisure time physical activity: a survey of activity levels, beliefs and deterrents. *Age Ageing* 33(31): 287-292, 2004.
10. Curry BS, Chengkalath D, Crouch GJ, Romance M, Manns PJ. Acute effects of dynamic stretching, static stretching, and light aerobic activity on muscular performance in women. *J Strength Cond Res* 23(61): 1811-1819, 2009.
11. Dotan R, Bar-Or O. Load optimization for the Wingate anaerobic test. *Eur J Appl Physiol Occup Physiol* 51(31): 409-417, 1983.
12. Faulkner SH, Ferguson RA, Gerrett N, Hupperets M, Hodder SG, Havenith G. Reducing muscle temperature drop post warm-up improves sprint cycling performance. *Med Sci Sports Exerc* 45(2): 359-365, 2012.
13. Fowles JR, Sale DG, MacDougall JD. Reduced strength after passive stretch of the human plantarflexors. *J Appl Physiol* 89(3): 1179-1188, 2000.
14. Franco BL, Signorelli GR, Trajano GS, Costa PB, de Oliveira CG. Acute effects of three different stretching protocols on the Wingate test performance. *J Sports Sci Med* 11(11): 1, 2012.
15. Gacesa JZP, Barak OF, Grujic NG. Maximal anaerobic power test in athletes of different sport disciplines. *J Strength Cond Res* 23(31): 751-755, 2009.
16. Gipson AS, Jones J, Ritchey EN, Murphy C, Grimes H, Coons JM. The Acute Effects of a Dynamic Stretching Protocol on Wingate Performance. *Int J Exerc Sci* 7(41): 2, 2014.
17. Greer F, Morales J, Coles M. Wingate performance and surface EMG frequency variables are not affected by caffeine ingestion. *Appl Physiol Nutr Metab* 31(51): 597-603, 2006.



18. Hoffman J, Ratamess N, Kang J, Mangine G, Faigenbaum A, Stout J. Effect of creatine and  $\beta$ -alanine supplementation on performance and endocrine responses in strength/power athletes. *Int J Sport Nutr Exerc Metab* 16(4): 430-446, 2006.
19. Hoffman JR, Kang J, Ratamess NA, Jennings PF, Mangine GT, Faigenbaum AD. Effect of Nutritionally Enriched Coffee Consumption on Aerobic and Anaerobic Exercise Performance. *J Strength Cond Res* 21(21): 456-459, 2007.
20. Leon C, Oh H-J, Rana S. A purposeful dynamic stretching routine. *Strategies* 25(51): 16-19, 2012.
21. Little T, Williams AG. Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. *J Strength Cond Res* 20(1): 203-307, 2006.
22. Manning JM. American college of sports medicine: Resource manual for guidelines for exercise testing and prescription. 6th ed Baltimore: Lippincott Williams & Wilkins, 1999.
23. McLester JR, Green JM, Chouinard JL. Effects of standing vs. seated posture on repeated Wingate performance. *J Strength Cond Res* 18(41): 816-820, 2004.
24. Nelson AG, Driscoll NM, Landin DK, Young MA, Schexnayder IC. Acute effects of passive muscle stretching on sprint performance. *J Sports Sci* 23(51): 449-454, 2005.
25. Nelson AG, Kokkonen J, Arnall DA. Acute muscle stretching inhibits muscle strength endurance performance. *J Strength Cond Res* 19(21): 338-343, 2005.
26. Ricard MD, Hills-Meyer P, Miller MG, Michael TJ. The effects of bicycle frame geometry on muscle activation and power during a Wingate anaerobic test. *J Sports Sci Med* 5(11): 25, 2006.
27. Samson M, Button DC, Chaouachi A, Behm DG. Effects of dynamic and static stretching within general and activity specific warm-up protocols. *J Sports Sci Med* 11(2): 279, 2012.
28. Souissi N, Sesboüé B, Gauthier A, Larue J, Davenne D. Effects of one night's sleep deprivation on anaerobic performance the following day. *Eur J Appl Physiol* 89(3-41): 359-366, 2003.
29. Taylor K-L, Sheppard JM, Lee H, Plummer N. Negative effect of static stretching restored when combined with a sport specific warm-up component. *J Sci Med Sport* 12(61): 657-661, 2009.
30. Tomaras EK, MacIntosh BR. Less is more: standard warm-up causes fatigue and less warm-up permits greater cycling power output. *J Appl Physiol* 111(11): 228-235, 2011.
31. Yamaguchi T, Ishii K. Effects of static stretching for 30 seconds and dynamic stretching on leg extension power. *J Strength Cond Res* 19(31): 677-683, 2005.
32. Yamaguchi T, Ishii K, Yamanaka M, Yasuda K. Acute effects of dynamic stretching exercise on power output during concentric dynamic constant external resistance leg extension. *J Strength Cond Res* 21(41): 1238-1244, 2007.